Introduction

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Fractional calculus and its applications

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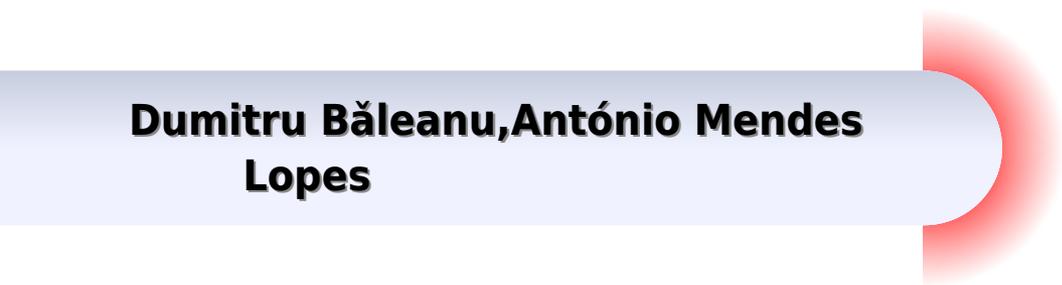[3]Potsdam Institute for Climate Impact Research, Telegrafenberg A31, 14473 Potsdam, Germany

Fractional calculus was formulated in 1695, shortly after the development of classical calculus. The earliest systematic studies were attributed to Liouville, Riemann, Leibniz, etc. [1,2]. For a long time, fractional calculus has been regarded as a pure mathematical realm without real applications. But, in recent decades, such a state of affairs has been changed. It has been found that fractional calculus can be useful and even powerful, and an outline of the simple history about fractional calculus, especially with applications, can be found in Machado *et al.* [3].

Now, *fractional calculus and its applications* is undergoing rapid developments with more and more convincing applications in the real world [4,5]. This Theme Issue, including one review article and 12 research papers, can be regarded as a continuation of our first special issue of *European Physical Journal Special Topics* in 2011 [4], and our second special issue of *International Journal of Bifurcation and Chaos* in 2012 [5]. These selected papers were mostly reported in *The Fifth Symposium on Fractional Derivatives and Their Applications* (FDTA'11) that was held in Washington DC, USA in 2011.

The first paper presents an overview of chaos synchronization of coupled fractional differential systems. A list of coupling schemes are presented, including one-way coupling, Pecora–Carroll coupling, active–passive decomposition coupling, bidirectional coupling and other unidirectional coupling configurations. Meanwhile, several extended concepts of synchronizations are introduced, namely projective synchronization, hybrid projective synchronization, function projective synchronization, generalized synchronization and generalized projective synchronization. Corresponding to different

Fractional Calculus And Its Applications Research Papers

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    Recent Trends in Fractional Calculus and Its Applications Praveen Agarwal,Luis Vázquez Martínez,Ervin K. Lenzi,2024-07-02 Recent Trends in Fractional Calculus and Its Applications addresses the answer to this very basic question Why is Fractional Calculus important Until recent times Fractional Calculus was considered as a rather esoteric mathematical theory without applications but in the last few decades there has been an explosion of research activities on the application of Fractional Calculus to very diverse scientific fields ranging from the physics of diffusion and advection phenomena to control systems to finance and economics An important part of mathematical modelling of objects and processes is a description of their dynamics The term Fractional Calculus is more than 300 years old It is a generalization of the ordinary differentiation and integration to noninteger arbitrary order The subject is as old as the calculus of differentiation and goes back to times when Leibniz Gauss and Newton invented this kind of calculation Several mathematicians contributed to this subject over the years People like Liouville Riemann and Weyl made major contributions to the theory of Fractional Calculus In recent decades the field of Fractional Calculus has attracted the interest of researchers in several areas including mathematics physics chemistry engineering finance and social sciences Provides the most recent and up to date developments in the Fractional Calculus and its application areas Presents pre preparation ideas to help researchers scientists clinicians face the new challenges in the application of fractional differential equations Helps researchers and scientists understand the importance of the Fractional Calculus to solve many problems in Biomedical Engineering and applied sciences   Advances in Non-Integer Order Calculus and Its Applications Agnieszka B. Malinowska,Dorota Mozyrska,Łukasz Sajewski,2019-04-17 This book provides an overview of some recent findings in the theory and applications of non integer order systems Discussing topics ranging from the mathematical foundations to technical applications of continuous time and discrete time fractional calculus it includes 22 original research papers and is subdivided into four parts Mathematical Foundations Approximation Modeling and Simulations Fractional Systems Analysis and Control Applications The papers were selected from those presented at the 10th International Conference of Non integer Order Calculus and its Applications which was held at the Bialystok University of Technology Poland September 20 21 2018 Thanks to the broad spectrum of topics covered the book is suitable for researchers from applied mathematics and engineering It is also a valuable resource for graduate students as well as for scholars looking for new mathematical tools

    Recent Developments in Theory and Applications of Fractional Order Systems Mehmet Yavuz,Dharmendra Kumar Singh,Stuart Townley,2025-08-11 Recent Developments in Theory and Applications of Fractional Order Systems presents a rigorous and thorough analysis of various aspects of Fractional Calculus The book provides readers with a thorough understanding of fundamental concepts and methods of applied mathematics utilized in a variety of scientific and engineering disciplines The authors present each computational modeling concept with a definition methods theorems and

observations followed by typical application problems and step by step solutions Each topic is covered in detail followed typically by several meticulously worked out examples and a problem set containing many additional related problems In addition the book discusses recent developments and the latest research on Fractional Calculus and its applications demonstrating important applications in Engineering Computer Science Management Social Science and the Humanities Provides readers with a thorough understanding of fundamental concepts and methods of applied mathematics utilized in a variety of scientific and engineering disciplines Presents a systematic introduction to most of the important special functions in Fractional Calculus that commonly arise in scientific and engineering practice Explores many salient computational modeling properties Analyzes theoretical and practical problems in Fractional Calculus in fields such as Engineering Computer Science Management Social Science and the Humanities *Recent Developments in Fractional Calculus: Theory, Applications, and Numerical Simulations* Lakhveer Kaur,Pushpendra Kumar,2025-05-30 This book discusses recent developments in fractional calculus and fractional differential equations in a very elaborate manner and is of interest to research scholars academicians and scientists who want to enhance the knowledge in the context of new insights and mathematical ideas in fractional calculus and its emerging applications in various fields It focuses on strengthening the existing results along with identifying the practical challenges encountered The purpose of this collection is to provide comprehension of articles that reflect recent mathematical results as well as some results in applied sciences untouched by the tools and techniques of fractional calculus along with their modelling and computation having applications in diverse arenas **Theory And Applications of Fractional Differential Equations** A. Anatolii Aleksandrovich Kilbas,Hari Mohan Srivastava,Juan J. Trujillo,2006 This monograph provides the most recent and up to date developments on fractional differential and fractional integro differential equations involving many different potentially useful operators of fractional calculus The subject of fractional calculus and its applications that is calculus of integrals and derivatives of any arbitrary real or complex order has gained considerable popularity and importance during the past three decades or so due mainly to its demonstrated applications in numerous seemingly diverse and widespread fields of science and engineering Some of the areas of present day applications of fractional models include Fluid Flow Solute Transport or Dynamical Processes in Self Similar and Porous Structures Diffusive Transport akin to Diffusion Material Viscoelastic Theory Electromagnetic Theory Dynamics of Earthquakes Control Theory of Dynamical Systems Optics and Signal Processing Bio Sciences Economics Geology Astrophysics Probability and Statistics Chemical Physics and so on In the above mentioned areas there are phenomena with estrange kinetics which have a microscopic complex behaviour and their macroscopic dynamics can not be characterized by classical derivative models The fractional modelling is an emergent tool which use fractional differential equations including derivatives of fractional order that is we can speak about a derivative of order 1 3 or square root of 2 and so on Some of such fractional models can have solutions which are non differentiable but continuous functions such as

Weierstrass type functions Such kinds of properties are obviously impossible for the ordinary models What are the useful properties of these fractional operators which help in the modelling of so many anomalous processes From the point of view of the authors and from known experimental results most of the processes associated with complex systems have non local dynamics involving long memory in time and the fractional integral and fractional derivative operators do have some of those characteristics This book is written primarily for the graduate students and researchers in many different disciplines in the mathematical physical engineering and so many others sciences who are interested not only in learning about the various mathematical tools and techniques used in the theory and widespread applications of fractional differential equations but also in further investigations which emerge naturally from or which are motivated substantially by the physical situations modelled mathematically in the book This monograph consists of a total of eight chapters and a very extensive bibliography The main objective of it is to complement the contents of the other books dedicated to the study and the applications of fractional differential equations The aim of the book is to present in a systematic manner results including the existence and uniqueness of solutions for the Cauchy type problems involving nonlinear ordinary fractional differential equations explicit solutions of linear differential equations and of the corresponding initial value problems through different methods closed form solutions of ordinary and partial differential equations and a theory of the so called sequential linear fractional differential equations including a generalization of the classical Frobenius method and also to include an interesting set of applications of the developed theory Key features It is mainly application oriented It contains a complete theory of Fractional Differential Equations It can be used as a postgraduate level textbook in many different disciplines within science and engineering It contains an up to date bibliography It provides problems and directions for further investigations Fractional Modelling is an emergent tool with demonstrated applications in numerous seemingly diverse and widespread fields of science and engineering It contains many examples and so on   **The Fundamentals of Fractional Calculus** Dharmendra Kumar Singh,Mehmet Yavuz,2025-09-23 Fractional calculus is one of the most important divisions of theoretical and applied mathematics This new book presents a wide variety of interesting technologies and practices used in fractional calculus providing detailed insight into recent developments and the latest research in the field of science engineering etc using fractional calculus The result of the teaching experiences of the editors and authors to engineering and science students the volume discusses fractional calculus via generalized functions and integral transforms of pathway type Laplace transformation of fractional integrals and derivatives estimating the order of derivation in a fractional differential equation a new class of integro differential equations with non singular differential operators various uses of the Caputo approach a gingerbread man discrete system etc The various applications of fractional calculus are shown with examples such as for creating and or solving epidemic models alcoholism models model for divorce dynamics and more Giving a rigorous and thorough analysis of various aspects of fractional calculus this volume helps scientific readers as well as researchers working

in the area of fractional calculus to establish the key steps followed in the research methodology and concept development **Proceedings of the International Conference on Fractional Differentiation and its Applications (ICFDA'21)** Andrzej Dzielinski,Dominik Sierociuk,Piotr Ostalczyk,2022-04-26 This book touches upon various aspects of a very interesting and growing in popularity category of models of dynamical systems These are the so called fractional order systems Such models are not only relevant for many fields of science and technology but may also find numerous applications in other disciplines applying the mathematical modelling tools Thus the book is intended for a very wide audience of professionals who want to expand their knowledge of systems modelling and its applications The book includes the selections of papers presented at the International Conference on Fractional Calculus and its Applications organized by the Warsaw University of Technology and was held online on 6 8 September 2021 The International Conference on Fractional Calculus and its Applications ICFDA has an almost twenty years history It started in Bordeaux France in 2004 followed by Porto Portugal 2006 Istanbul Turkey 2008 Badajoz Spain 2010 Nanjing China 2012 Catania Italy 2014 Novi Sad Serbia 2016 Amman Jordan 2018 Next ICFDA was planned in 2020 in Warsaw Poland but COVID 19 pandemic shifted it to 6 8 September 2021 Hence the organizers were forced to change the form of the conference to the online one In the volume twenty eight high quality research papers presented during the ICFDA 2021 eleven Regular Sessions with an additional online Discussion Session are presented The presented papers are scientifically inspiring leading to new fruitful ideas They cover a very broad range of many disciplines Nowadays and especially in such a subject as fractional calculus it is very difficult to assign papers to specific scientific areas So many of the papers included have an interdisciplinary character Methods of Mathematical Modelling and Computation for Complex Systems Jagdev Singh,Hemen Dutta,Devendra Kumar,Dumitru Baleanu,Jordan Hristov,2021-08-26 This book contains several contemporary topics in the areas of mathematical modelling and computation for complex systems The readers find several new mathematical methods mathematical models and computational techniques having significant relevance in studying various complex systems The chapters aim to enrich the understanding of topics presented by carefully discussing the associated problems and issues possible solutions and their applications or relevance in other scientific areas of study and research The book is a valuable resource for graduate students researchers and educators in understanding and studying various new aspects associated with complex systems Key Feature The chapters include theory and application in a mix and balanced way Readers find reasonable details of developments concerning a topic included in this book The text is emphasized to present in self contained manner with inclusion of new research problems and questions **Fractional Calculus and Its Applications in Physics** Dumitru Baleanu,Devendra Kumar,2019 This eBook is a collection of articles from a Frontiers Research Topic Frontiers Research Topics are very popular trademarks of the Frontiers Journals Series they are collections of at least ten articles all centered on a particular subject With their unique mix of varied contributions from Original Research to Review Articles Frontiers Research Topics unify the

most influential researchers the latest key findings and historical advances in a hot research area Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers Editorial Office frontiersin org about contact   *Fractional Calculus* Roy Abi Zeid Daou,Xavier Moreau,2014-01-12 After presenting the first volume of this two volume book presenting a lot of mathematical and theoretical studies and research related to non integer calculus the second volume illustrates applications related to this domain This volume is made up of 11 chapters The first chapter presents the heuristic power of the non integer differential operators in physics starting from the chaos to the emergence the auto organizations and the holistic rules The second chapter shows the dynamics of the fractional order chaotic systems along with some applications The third chapter represents the pressure control of gas engines by non integer order controllers by showing a novel trend in the application of the fractional calculus to automotive systems Chapter 4 shows the way to model fractional order equations using state space modeling along with some applications Another application related to this domain is the thermal diffusive interface Chapter 5 shows the analysis of a semi infinite diffuse plane medium along with the equations that model this medium and some frequency and time domain responses However Chapter 6 treats this problem by controlling this plant using the well known CRONE controller Chapter 8 presents the adaptive second order fractional sliding mode control with an application to a water tanks level system Chapter 9 treats the mechanical aspect by showing the features of the fractional operators applied to this domain Also Chapter Nine presents the theory of diffusive stresses based on the fractional advection diffusion equation The modeling of drug diffusion during general anesthesia using Fractional Calculus is shown in Chapter 10 and is considered as another application related to the biomedical field Finally Chapter 11 represents an overview of the fractional fuzzy controllers by showing the analysis the synthesis and the implementation of this module To sum up this second volume presents applications of fractional calculus in several engineering domains as the thermal the automotive the mechanical the biomedical and much more Note that this volume was preceded by a first volume that focuses on the mathematical and theoretical aspects of fractional calculus

   Computational Science and its Applications A. H. Siddiqi,R. C. Singh,G. D. Veerappa Gowda,2020-10-20 Computational science is a rapidly growing multidisciplinary field concerned with the design implementation and use of mathematical models to analyze and solve real world problems It is an area of science that spans many disciplines and which involves the development of models and allows the use of computers to perform simulations or numerical analysis to understand problems that are computational and theoretical Computational Science and its Applications provides an opportunity for readers to develop abilities to pose and solve problems that combine insights from one or more disciplines from the natural sciences with mathematical tools and computational skills This requires a unique combination of applied and theoretical knowledge and skills The topics covered in this edited book are applications of wavelet and fractals modeling by partial differential equations on flat structure as well as on graphs and networks computational linguistics prediction of natural calamities and

diseases like epilepsy seizure heart attack stroke biometrics modeling through inverse problems interdisciplinary topics of physics mathematics and medical science and modeling of terrorist attacks and human behavior The focus of this book is not to educate computer specialists but to provide readers with a solid understanding of basic science as well as an integrated knowledge on how to use essential methods from computational science Features Modeling of complex systems Cognitive computing systems for real world problems Presentation of inverse problems in medical science and their numerical solutions Challenging research problems in many areas of computational science This book could be used as a reference book for researchers working in theoretical research as well as those who are doing modeling and simulation in such disciplines as physics biology geoscience and mathematics and those who have a background in computational science **Non-Integer Order Calculus and its Applications** Piotr Ostalczyk,Dominik Sankowski,Jacek Nowakowski,2018-03-22 This book focuses on fractional calculus presenting novel advances in both the theory and applications of non integer order systems At the end of the twentieth century it was predicted that it would be the calculus of the twenty first century and that prophecy is confirmed year after year Now this mathematical tool is successfully used in a variety of research areas like engineering e g electrical mechanical chemical dynamical systems modeling analysis and synthesis e g technical biological economical as well as in multidisciplinary areas e g biochemistry electrochemistry As well as the mathematical foundations the book concentrates on the technical applications of continuous time and discrete time fractional calculus investigating the identification analysis and control of electrical circuits and dynamical systems It also presents the latest results Although some scientific centers and scientists are skeptical and actively criticize the applicability of fractional calculus it is worth breaking through the scientific and technological walls Because the fractional community is growing rapidly there is a pressing need for the exchange of scientific results The book includes papers presented at the 9th International Conference on Non integer Order Calculus and Its Applications and is divided into three parts Mathematical foundations Fractional systems analysis and synthesis System modelingSeven papers discuss the mathematical foundations twelve papers address fractional order analysis and synthesis and three focus on dynamical system modeling by the fractional order differential and difference equations It is a useful resource for fractional calculus scientific community **Fractional Calculus and Its Applications** ,2013 **Computational Modeling and Sustainable Energy** Brajesh Kumar Jha,Navnit Jha,Jwngsar Brahma,Mehmet Yavuz,2025-02-24 This book features best selected research papers presented at International Conference on Computational Modeling and Sustainable Energy ICCMSE 2023 held at Pandit Deendayal Energy University Gandhinagar Gujarat India during December 15 17 2023 It comprises high quality research work by academicians and industrial experts in the field of machine learning mobile computing natural language processing fuzzy computing green computing human computer interaction information retrieval intelligent control data mining and knowledge discovery evolutionary computing big data cloud computing business intelligence Internet security pattern recognition and sustainable energy **Fractional**

Calculus and Fractional Processes with Applications to Financial Economics Hasan Fallahgoul,Sergio Focardi,Frank Fabozzi,2016-10-06 Fractional Calculus and Fractional Processes with Applications to Financial Economics presents the theory and application of fractional calculus and fractional processes to financial data Fractional calculus dates back to 1695 when Gottfried Wilhelm Leibniz first suggested the possibility of fractional derivatives Research on fractional calculus started in full earnest in the second half of the twentieth century The fractional paradigm applies not only to calculus but also to stochastic processes used in many applications in financial economics such as modelling volatility interest rates and modelling high frequency data The key features of fractional processes that make them interesting are long range memory path dependence non Markovian properties self similarity fractal paths and anomalous diffusion behaviour In this book the authors discuss how fractional calculus and fractional processes are used in financial modelling and finance economic theory It provides a practical guide that can be useful for students researchers and quantitative asset and risk managers interested in applying fractional calculus and fractional processes to asset pricing financial time series analysis stochastic volatility modelling and portfolio optimization Provides the necessary background for the book s content as applied to financial economics Analyzes the application of fractional calculus and fractional processes from deterministic and stochastic perspectives   Integral Methods in Science and Engineering Christian Constanda,Bardo E.J. Bodmann,Haroldo F. de Campos Velho,2013-08-13 Advances in science and technology are driven by the development of rigorous mathematical foundations for the study of both theoretical and experimental models With certain methodological variations this type of study always comes down to the application of analytic or computational integration procedures making such tools indispensible With a wealth of cutting edge research in the field Integral Methods in Science and Engineering Progress in Numerical and Analytic Techniques provides a detailed portrait of both the construction of theoretical integral techniques and their application to specific problems in science and engineering The chapters in this volume are based on talks given by well known researchers at the Twelfth International Conference on Integral Methods in Science and Engineering July 23 27 2012 in Porto Alegre Brazil They address a broad range of topics from problems of existence and uniqueness for singular integral equations on domain boundaries to numerical integration via finite and boundary elements conservation laws hybrid methods and other quadrature related approaches The contributing authors bring their expertise to bear on a number of topical problems that have to date resisted solution thereby offering help and guidance to fellow professionals worldwide Integral Methods in Science and Engineering Progress in Numerical and Analytic Techniques will be a valuable resource for researchers in applied mathematics physics and mechanicaland electrical engineering for graduate students in these disciplines and for various other professionals who use integration as an essential tool in their work   **Applications in Physics, Part A** Vasily E. Tarasov,2019-02-19 This multi volume handbook is the most up to date and comprehensive reference work in the field of fractional calculus and its numerous applications This fourth volume collects authoritative

chapters covering several applications of fractional calculus in physics including classical and continuum mechanics

Theory and Applications of Non-integer Order Systems Artur Babiarz,Adam Czornik,Jerzy Klamka,Michał Niezabitowski,2016-09-15 This book collects papers from the 8th Conference on Non Integer Order Calculus and Its Applications that have been held on September 20 21 2016 in Zakopane Poland The preceding two conferences were held in Szczecin Poland in 2015 and in Opole Poland in 2014 This conference provides a platform for academic exchange on the theory and application of fractional calculus between domestic and international universities research institutes corporate experts and scholars The Proceedings of the 8th Conference on Non Integer Order Calculus and Its Applications 2016 brings together rigorously reviewed contributions from leading international experts The included papers cover novel various important aspects of mathematical foundations of fractional calculus modeling and control of fractional systems as well as controllability detectability observability and stability problems for this systems **Applications in Engineering, Life and Social Sciences, Part B** Dumitru Băleanu,António Mendes Lopes,2019-04-01 This multi volume handbook is the most up to date and comprehensive reference work in the field of fractional calculus and its numerous applications This eighth volume collects authoritative chapters covering several applications of fractional calculus in engineering life and social sciences including applications in signal and image analysis and chaos **Applications Of Fractional Calculus In Physics** Rudolf Hilfer,2000-03-02 Fractional calculus is a collection of relatively little known mathematical results concerning generalizations of differentiation and integration to noninteger orders While these results have been accumulated over centuries in various branches of mathematics they have until recently found little appreciation or application in physics and other mathematically oriented sciences This situation is beginning to change and there are now a growing number of research areas in physics which employ fractional calculus This volume provides an introduction to fractional calculus for physicists and collects easily accessible review articles surveying those areas of physics in which applications of fractional calculus have recently become prominent

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